Assessing Geomechanical Risks at GCS Sites Using the State of Stress Assessment Tool (SOSAT)

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NRAP
National Risk Assessment Partnership

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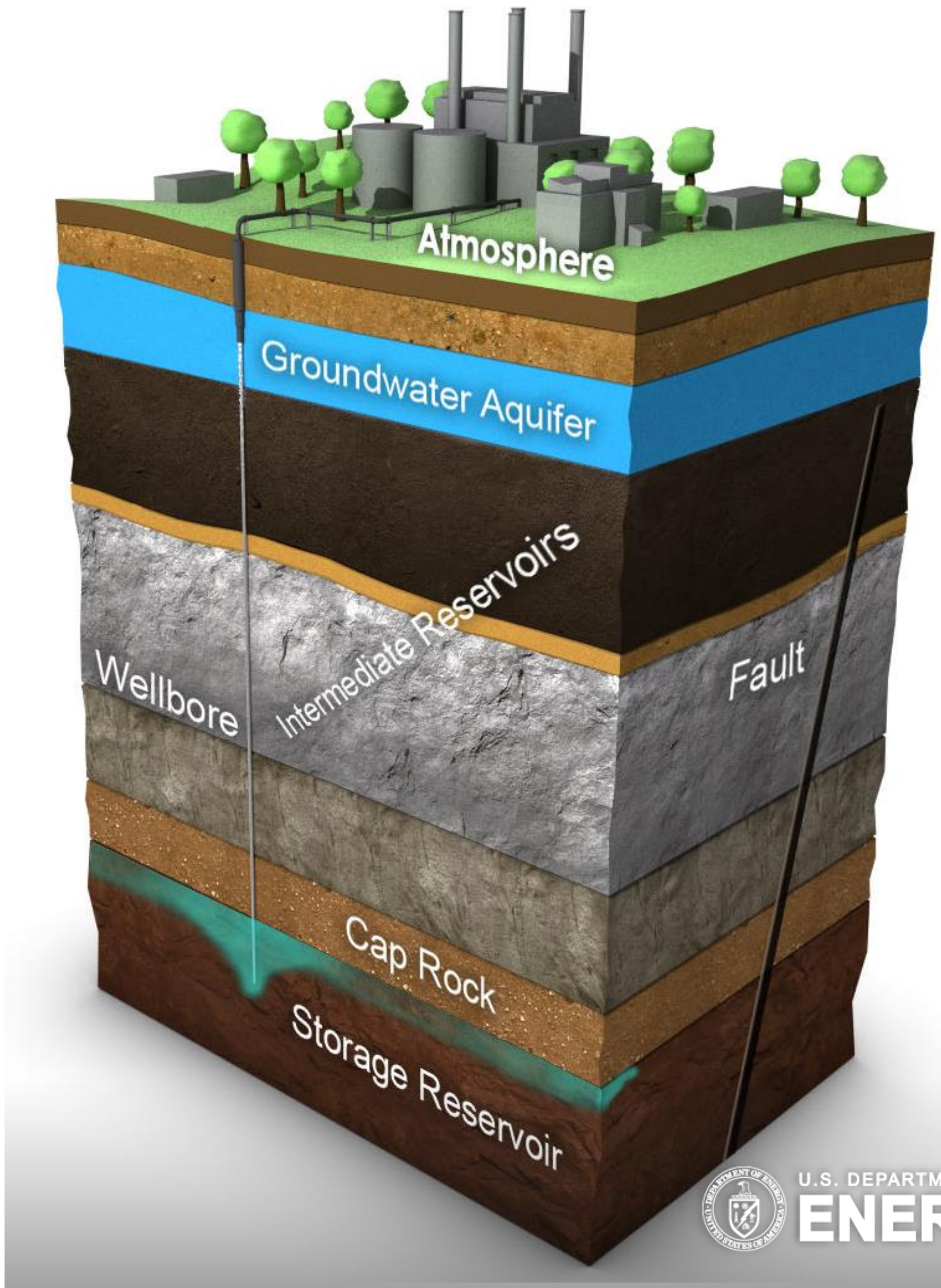


U.S. DEPARTMENT OF ENERGY

Outline

- **What is geomechanical risk?**
- **What is SOSAT?**
- **Example: using SOSAT to estimate risk based on:**
  - Frictional faulting (stress polygon)
  - Mini-frac stress measurement (wireline-based)
  - Absence of breakout (image log)

What is Geomechanical Risk?

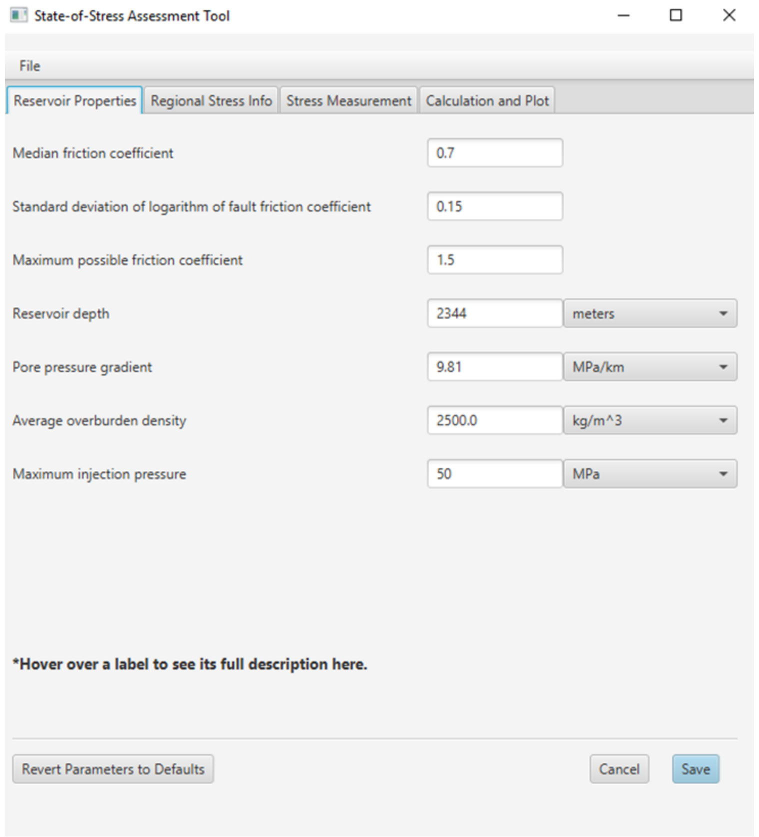
- **Leakage caused by unintentional hydraulic fracturing**
  - Occurs when the pore fluid pressure exceeds the minimum principal stress
  - Can occur in reservoir or the caprock

- **Induced seismicity**
  - Caused by change in stress on fault induced by elevated pore pressure
  - Can be caused directly by elevated pore pressure on fault
  - Can be caused indirectly by changes in stress even if local pore pressure is not elevated

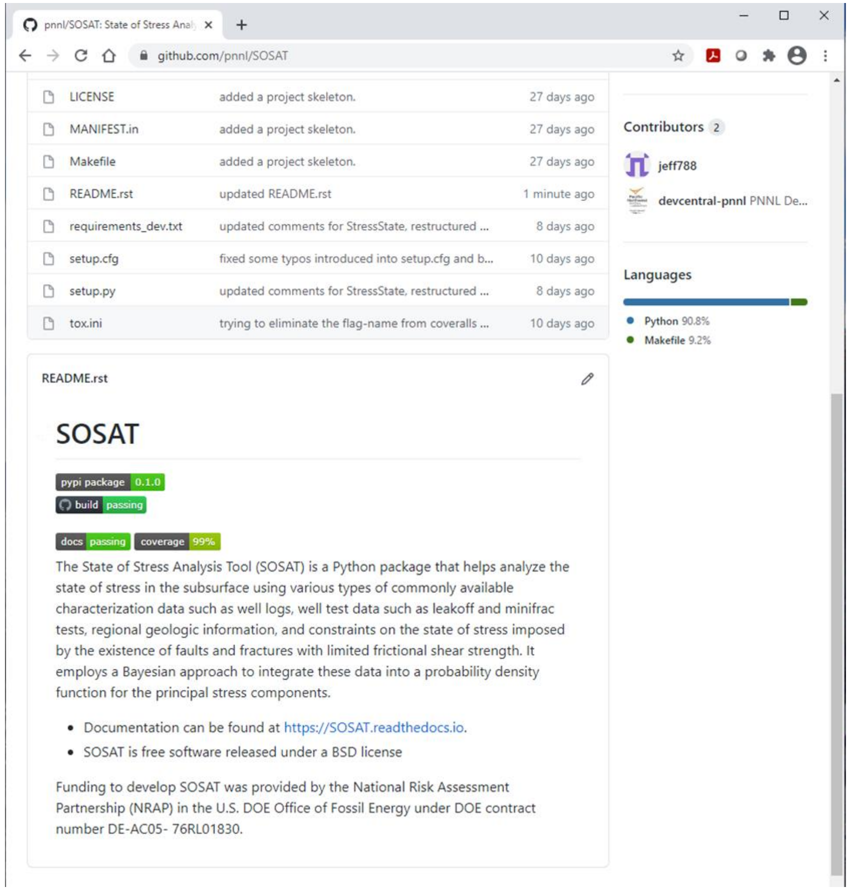
What is SOSAt?

State of Stress Assessment Tool (SOSAT)

- Allows user to input a wide variety of observations relevant to state of stress
- Computes probability distribution of the stress tensor at a point in the subsurface
- Can be applied to reservoir or surrounding formations
- GUI supports some features but there are some only supported through a Python interface



SOSAT is Now on GitHub (github.com/pnnl/SOSAT)



Does stress uncertainty matter?

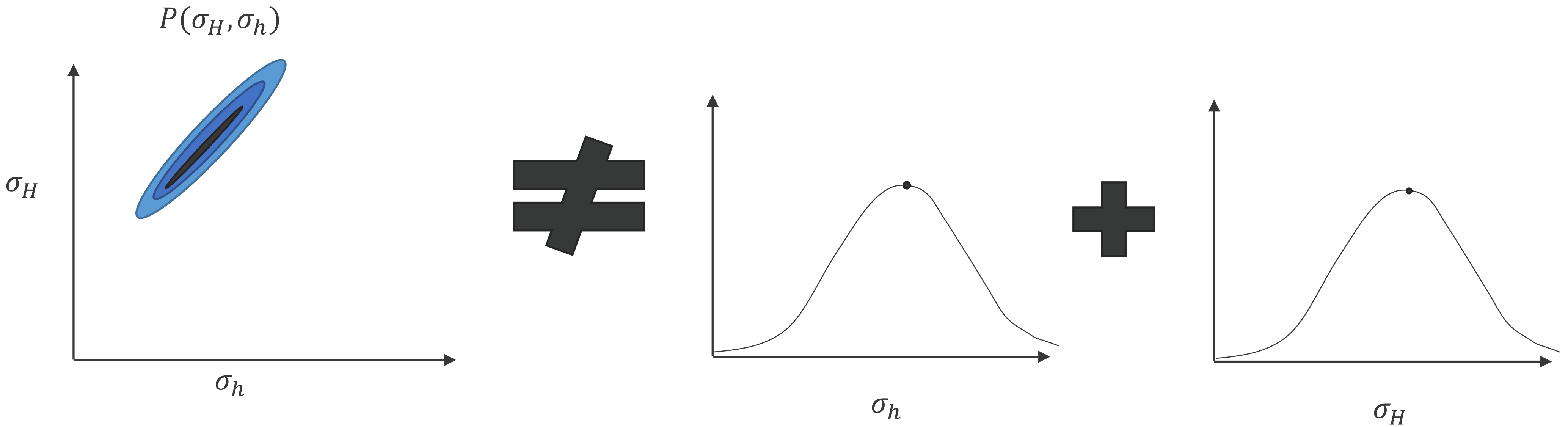
- **How will the information be used?**
  - Wellbore stability
  - Fracture initiation
  - Fracture height growth
  - Induced seismicity
- **What is the consequence of an error?**
  - Inconvenience
  - Delay
  - Lost revenue
  - Elevated costs
  - Environmental damage
  - Loss of life

Increasing importance of UQ

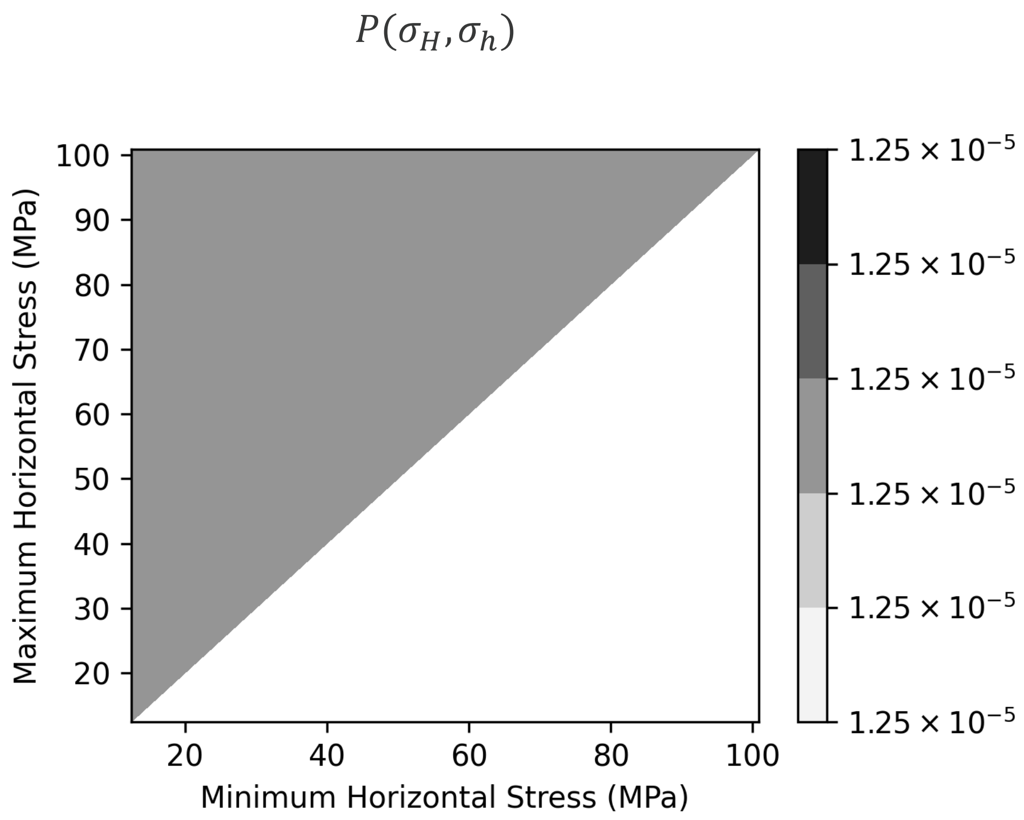
Applying Statistics to Tensors

Statistically, stress (and other tensors) should be thought of as a <u>joint</u> probability distribution of magnitudes and directions

There is often a correlation between principal stress components, so they cannot be treated as independent



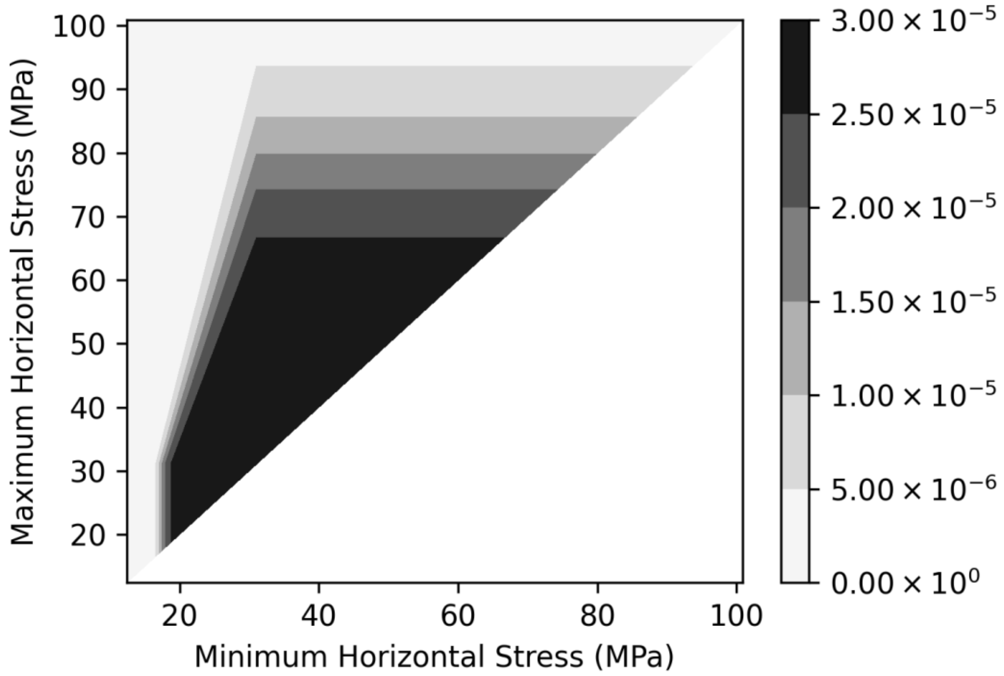
Prior Stress State Assumption



Begin with posterior assumption that all stress states where $\sigma_H > \sigma_h$ and both are compressive have equal probability

Frictional Faulting Constraint

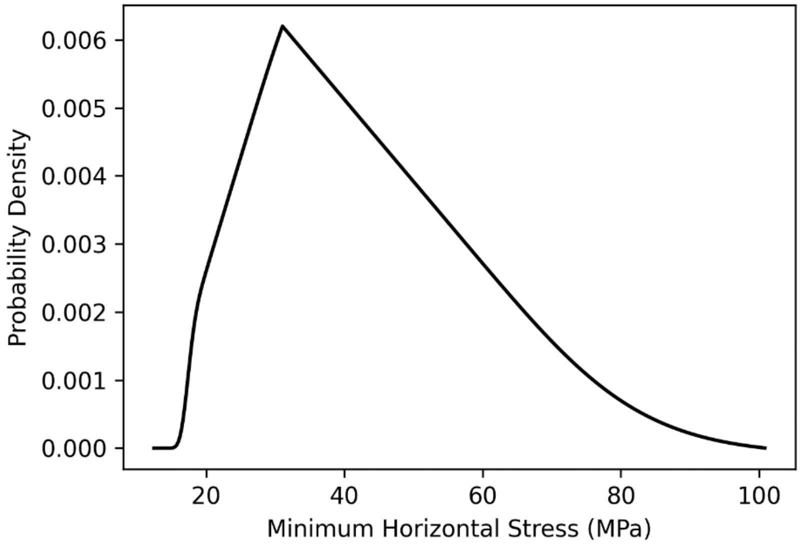
$P(\sigma_H, \sigma_h)$



Assert that stress cannot be larger than rock strength, which is assumed to be governed by frictional strength of faults and fractures

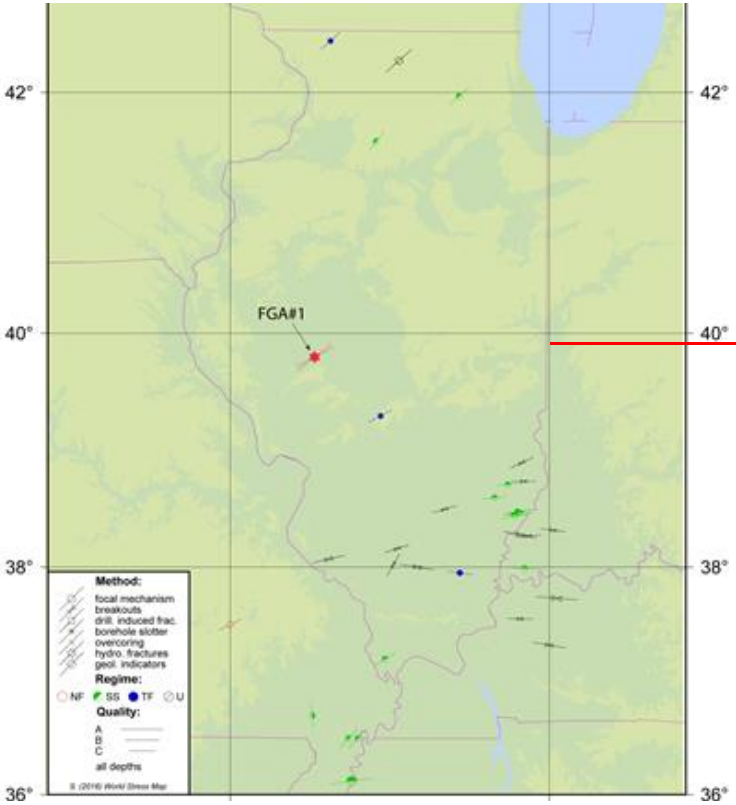
$$P(D|\sigma_H, \sigma_h) = 1 - \frac{1}{2}\operatorname{erfc}\left[-\frac{\ln\mu_c - \mu_o}{\sigma_\mu\sqrt{2}}\right]$$

μ_c	friction coefficient that would cause failure at a given stress state
μ_o	mean of the lognormal distribution for friction

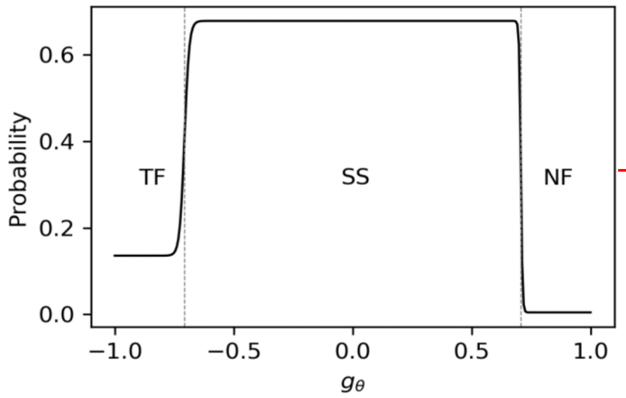


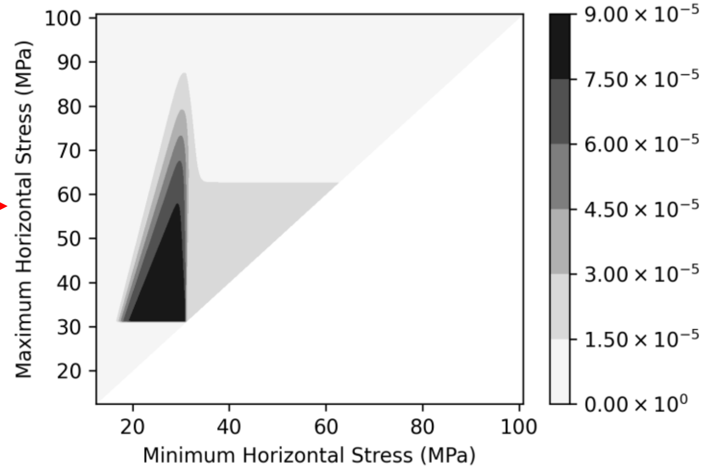
Regional Stress Observations

Most stress indicators in the area suggest a strike-slip state of stress, with some possibility of thrust faulting



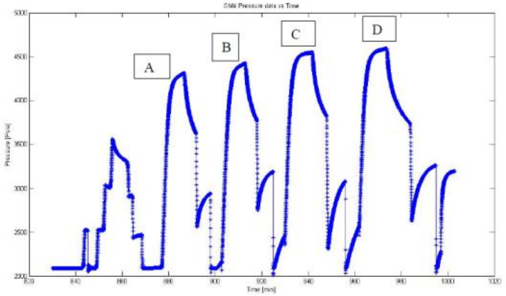
World Stress Map Database



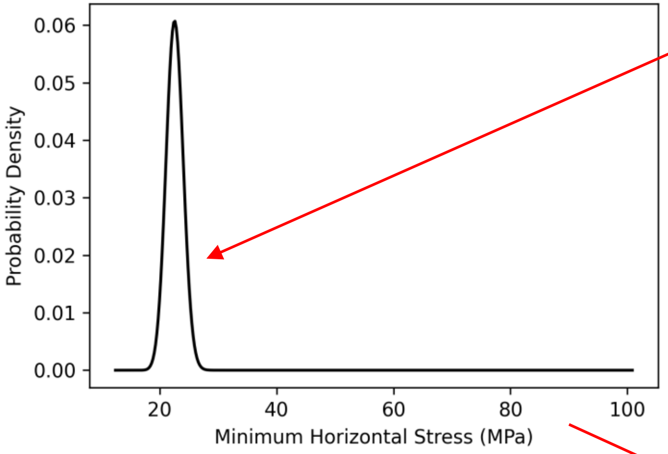


Minimum Principal Stress Measurement

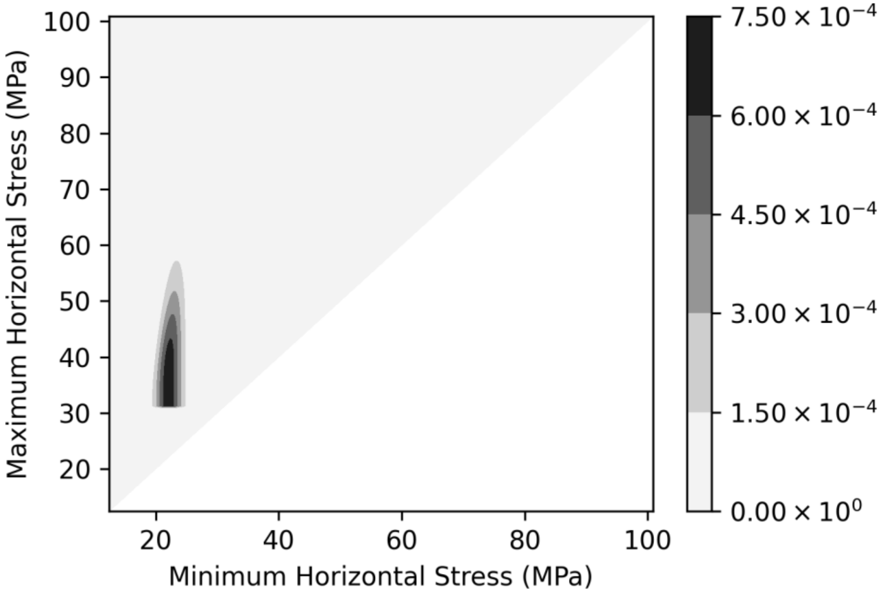
Mini-frac measurement

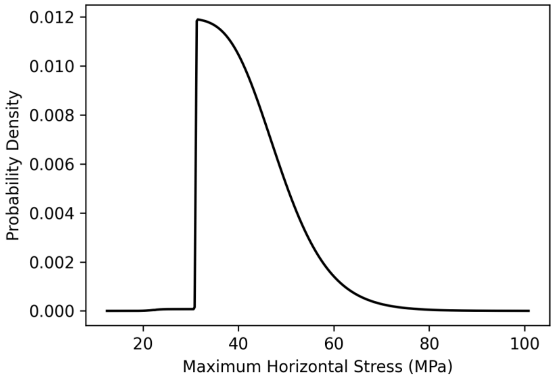


Add mini-frac stress measurement with normal distribution with mean of 22.1 MPa and standard deviation of 1.5 MPa

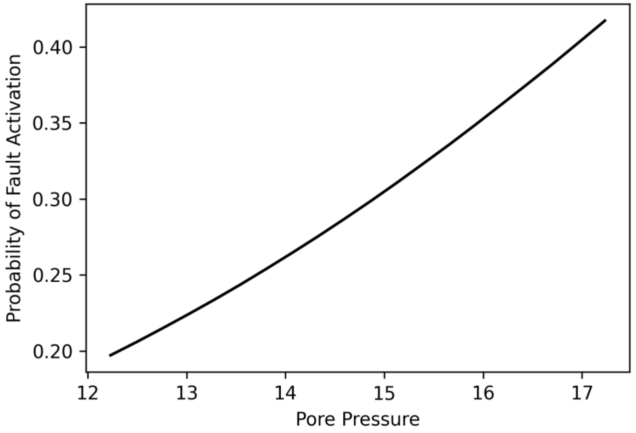


Risk of hydraulic fracturing is governed by this



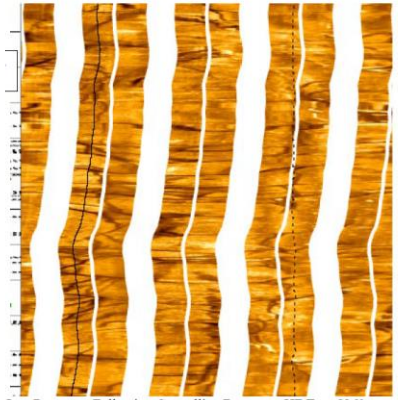


Risk of fault activation is governed by both stresses

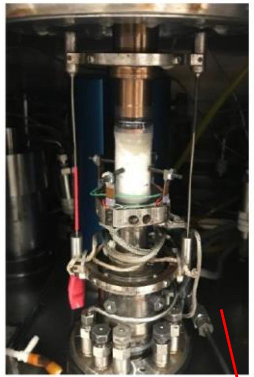


Constraint by Absence of Breakout

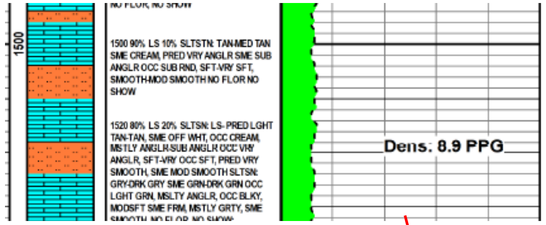
Image Logs



Core Tests



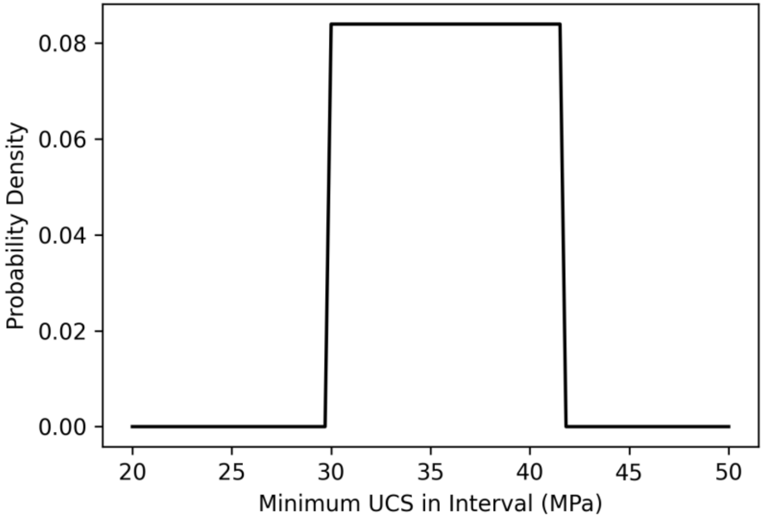
Mud Logs/Drilling Reports/ MWD Data



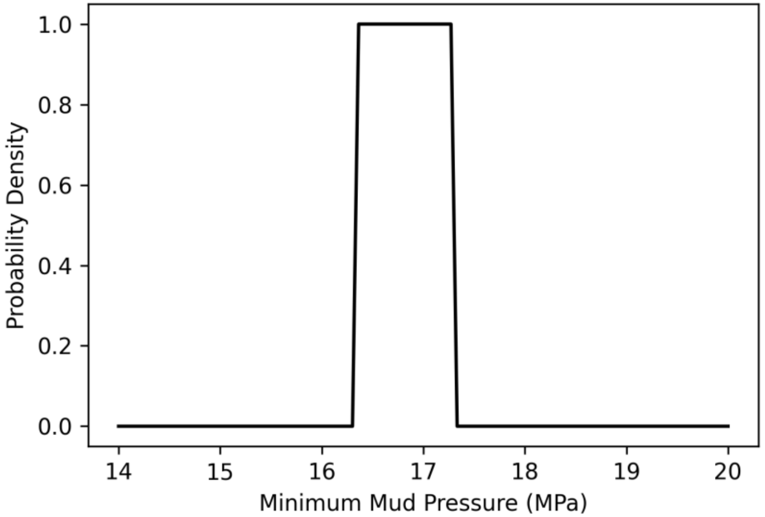
Add constraint based on the absence of breakouts and uncertainties in formation and mud properties

Formation of breakout depends on σ_h, σ_H, and:

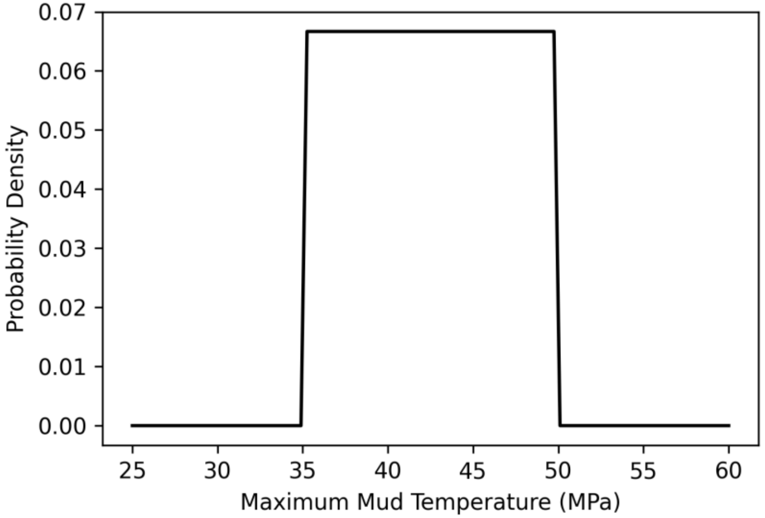
Minimum rock strength



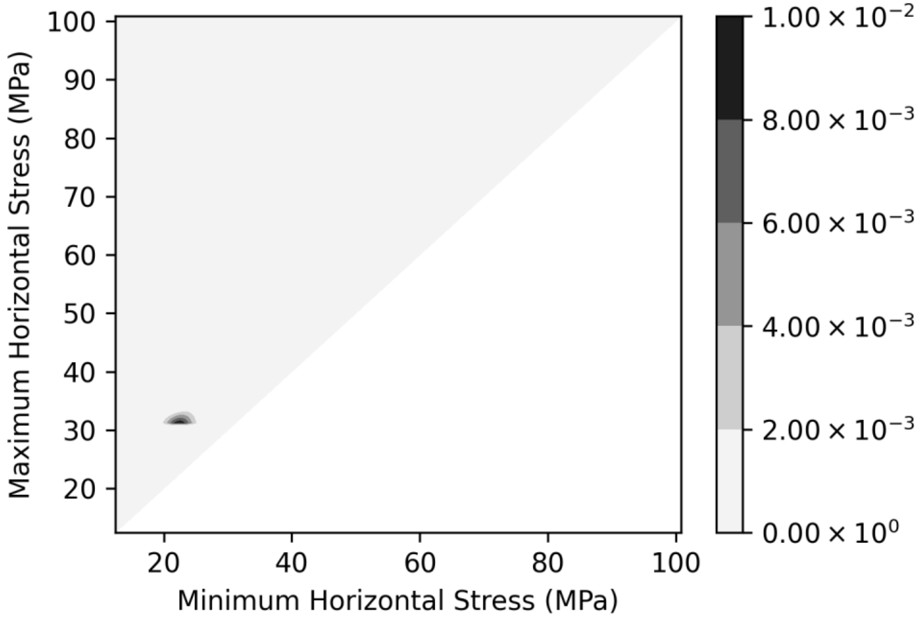
Minimum mud pressure

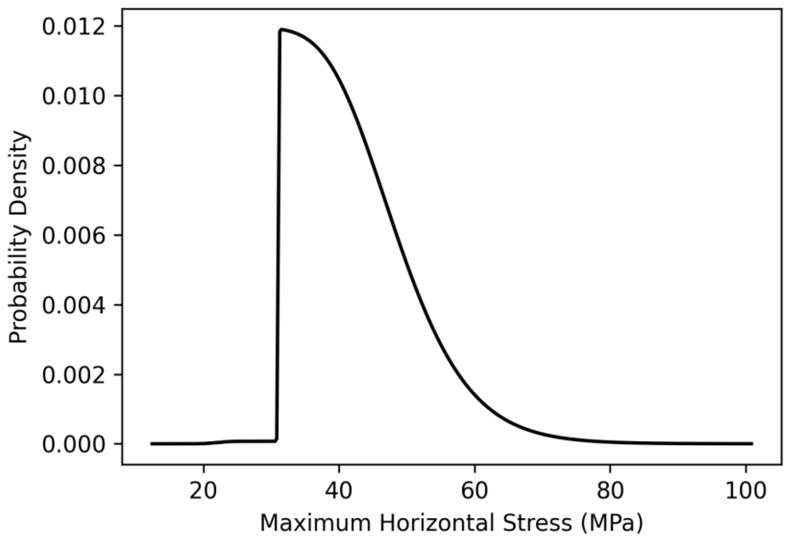


Maximum mud temperature

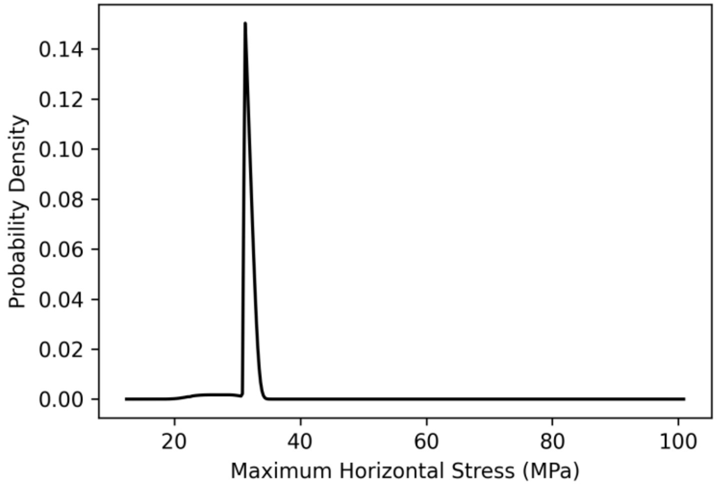


Constraint by Absence of Breakout





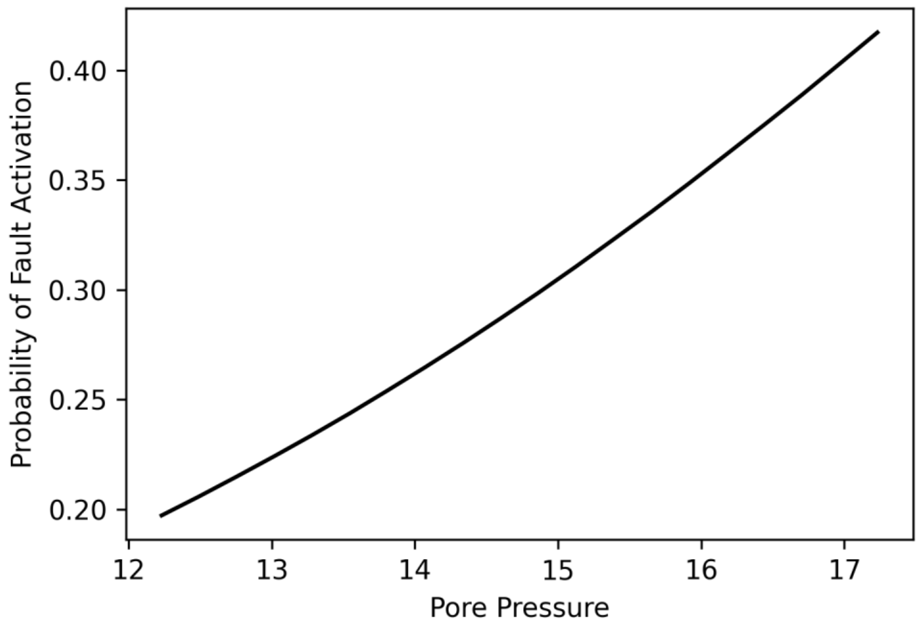
Without breakout constraint



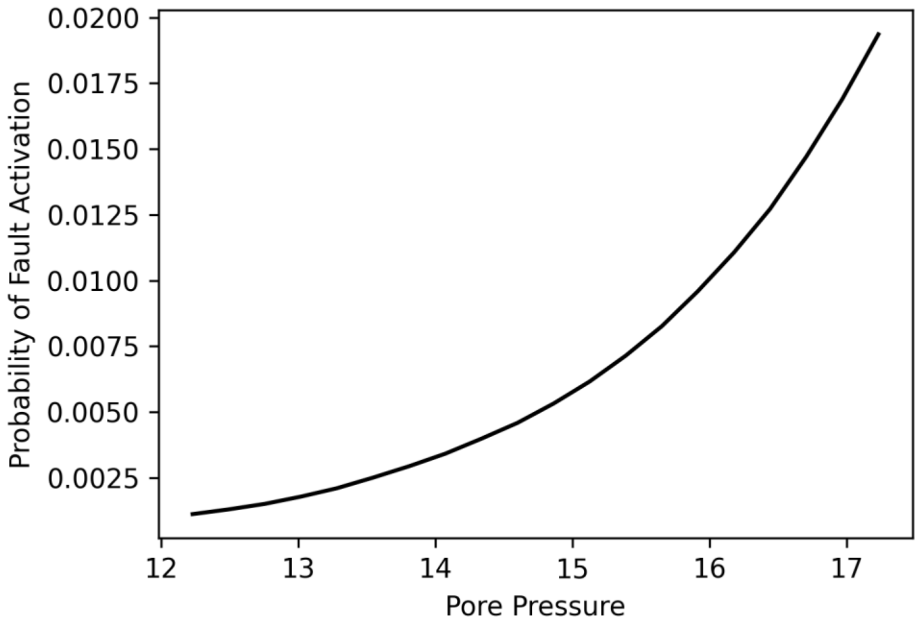
With breakout constraint

Constraint by Absence of Breakout

Risk of fault activation without breakout analysis



Risk of fault activation with breakout analysis



Future Plans/Learn More

- **2D Mapping along a formation**
  - Develop support for earthquake focal mechanisms
  - Automate pulling data from World Stress Map Database
- **Develop web-based GUI**

Download GUI and User's Manual:
https://edx.netl.doe.gov/nrap/state-of-stress-analysis-tool-sosat/

Tool User Forum:
https://edx.netl.doe.gov/workspace/forum/nrap-tools

Download/Install from GitHub or PyPi:
https://github.com/pnnl/SOSAT